Pioneer 10 and 11 Mission Support

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The current estimates of the Deep Space Network performance capability in tracking Pioneer 10 to the telecommunications limit and for Pioneer 11 Saturn encounter are discussed.

I. Introduction

The topic discussed here was previously discussed in a 1976 DSN Progress Report article (Ref. 1). Since the time of that article, the Pioneer 10 spacecraft has thresholded on the DSN 26-meter stations and considerable in-flight measured performance data have been gathered. New estimates of expected performance capability, based on the measured performance, indicate that for a 64-meter station with a 22-deg system noise temperature tracking above 30-deg elevation it should be possible to track Pioneer 10 spacecraft out to 34 AU, which will be reached by the spacecraft in the first part of 1985. This is over 5 AU farther than earlier estimates.

Unfortunately, revision of the Pioneer 11 expected performance at Saturn encounter, based on in-flight experience, has resulted in a reduction in estimated performance at Saturn which makes the Project's desired objective of 1024 b/s at Saturn appear to be out of reach with any practical performance improvements that could be achieved in the time available. It now appears that the new low-noise cones which will be installed prior to Saturn encounter (and were planned with the intention of trying to achieve 1024 b/s will be required just to make 512 b/s marginally possible.

II. Projected Spacecraft Life

The Pioneer 10 spacecraft is projected to have sufficient attitude control propellant (necessary for antenna pointing) out to 1989. The end-of-life projected by the Project is based on when the radioisotope thermoelectric generators (RTG) are expected to have degraded beyond the point where six science instruments can be operated (94.6 W). The new project estimate for reaching the 94.6-W point is late 1985 to mid 1986. If the instrument load were reduced to two instruments, only 90 W would suffice, which level the RTG's are projected to reach by the end of 1987.

The Pioneer 11 RTG prediction is to reach the minimum power for six science instruments in late 1986. (There are still some practical problems which must be solved by the Project in maintaining control of the spacecraft attitude with such a large round-trip light time in the latter part of the mission.)

III. Expected Telecommunications Performance for Pioneer 11 Saturn Encounter

At the closest approach to Saturn, the first week of September 1979, Pioneer 11 will be only 8 deg from the Sun,

heading into conjunction. The desired bit rate by the Project is 1024 b/s, which is the lowest bit rate at which full imaging capability can be achieved. For a description of the imaging instrument and the origin of its data rate requirement, see Ref. 2. Reference 1 had projected that 1024 bits would be marginally possible utilizing the listen-only mode of the new low-noise cones at a system temperature of 14.5 K. Figure 1 shows the updated estimates of Pioneer 10 and 11 downlink performance from the current time through 1983. Using Fig. 1, it can be seen that utilizing the existing 22 K system temperature in the diplex mode capability of the 64-meter stations, only 256 b/s is possible. The 18.5 K system temperature in the diplex mode of the low-noise cones which will be installed at all 64-meter stations prior to Saturn encounter will give a 0.75-dB improvement. From the chart it is seen that 18.5 K system temperature will make 512 b/s possible only near zenith. The listen-only capability of the new cones provides a 14.5 K system temperature, which represents a gain of 1.8 dB over the currently existing 22 K system temperature cones. The 1.8-dB improvement will make 512 b/s possible above about 15-deg elevation. Figure 1 assumes that the spacecraft antenna Earth-pointing is being maintained to within ±0.5 deg, which represents a 0.4-dB loss due to spacecraft antenna-pointing. With more frequent spacecraft precession manuevers to reduce this 0.4-dB loss, it should be possible to achieve the 512 b/s, continuously utilizing the listen-only mode.

The Pioneer 11 spacecraft will require extensive real-time commanding in order to execute its encounter sequence. Utilizing the listen-only mode will therefore require that a 26-meter station be scheduled simultaneously with the 64-meter station in order to handle the uplink. At the time of Saturn encounter, the Voyager and Pioneer view periods have considerable overlap, and Pioneer 10 and the Pioneer Venus Mission will also require continued attention. Therefore, as a practical matter, it will probably be possible to utilize the listen-only mode only for one or two weeks of the 60-day Saturn encounter period. Unfortunately, at the moment it looks like 1024 b/s will not be achievable even with the listen-only mode. At 512 b/s, pictures of 7-deg height instead of 14 deg would be possible at full resolution (7 deg being the look angle from the spacecraft perpendicular to the spin axis). The spacecraft does have a half-resolution mode which would make reduced-resolution 14-deg look angle pictures possible. The effects of the solar conjunction are not accounted for in Fig. 1, and it is expected that because the sunspot cycle was at its peak, significant effects in the telemetry performance would start occurring about 6 deg from the Sun.

IV. The Telecommunications Limit of Pioneer 10

Reference 1 had predicted the telecommunications limit for Pioneer 10 using the existing 64-meter configuration as 24.6 AU, or 28.4 AU if tracking above 30-deg elevation. Figure 2 shows the geocentric range of the Pioneer 10 spacecraft from 1983 through the start of 1990 and contains the revised performance estimates based on in-flight experience since the time of writing Ref. 1. The dB scale on the lefthand edge represents the received carrier power from Pioneer 10 spacecraft for the 64-meter antenna. The sloping curve, labeled 64-meter, 22-deg SNT (system noise temperature) represents the current best estimate of the threshold limit for Pioneer 10 with the existing 64-meter configuration. All the performance numbers on Fig. 1 assume that the spacecraft pointing is maintained within ±0.5 deg, which corresponds to a maximum loss due to spacecraft antenna-pointing of 0.4 dB. One-in-a-thousand deletion rate and the use of the 3-Hz loop in the Block IV receiver are also assumed. The curve for the 64-meter 22-deg SNT case represents the effect of ground antenna elevation. The elevation curve shows that the predicted threshold is 29 AU if tracking is desired as low as 10-deg elevation. Similarly, if tracking is restricted to above 30 deg elevation, the threshold is reached at 34 AU. However, if tracking were limited to above 30-deg elevation, it can be seen that the telecommunications limit is 34 AU, which would not be reached until the first of 1985. Tracking above 30-deg elevation is what has been used in estimating the telecommunications limit for Pioneer 10 for each of the possible performance improvements that will be discussed. The new low-noise cones that will be installed prior to Pioneer 11 Saturn encounter give an 18.5 K system noise temperature in the diplex mode, and from Fig. 1 it is seen that for tracking above 30-deg elevation the telecommunications limit is placed at slightly more than 37 AU, which is not reached until the first part of 1986.

If the listen-only mode were practical for support of Pioneer 10, the resulting 14.5 K system noise temperature would give a capability out to 42 AU, which is not reached until early 1988. Use of the listen-only mode for support of Pioneer 10 for extensive coverage is probably not practical because of the requirement to have a second antenna scheduled for transmitting the uplink in order to command the spacecraft. The 70-meter extension of the 64-meter antenna in the diplex mode with the 18.5-deg cone would give a capability out to almost 41 AU, which would be reached in the first half of 1987. Use of the diplex mode at 14.5 deg at the 70-meter would give coverage capability out to 46 AU, which would be reached in the first part of 1989. Of interest is a 100-meter antenna with 18.5 K system noise temperature (note that the currently discussed large-aperture antenna system of the DSN does not have an S-band capability) which would give a capability with the Pioneer 10 spacecraft design of 58 AU. Pioneer 10 would clearly be out of power but the spacecraft will reach 58 AU sometime in 1993. Figure 2 shows that the orbit of Neptune is at approximately 30 AU and the mean orbit of Pluto at 40 AU. Actually, Pluto is currently

closer to the Earth than Neptune, and its apoapsis range is as far as 49 AU.

Two cautions are in order with regard to estimating the end of the Pioneer 10 mission. The first is that the end of RTG life is only an estimate, and although the RTG performance has been following the updated prediction of its degradation for the past two years, it is possible for the rate of its degradation to change. The second is to notice the tremendous leverage that a small uncertainty in dB has in both range and time for the telecommunications limit. At the area of the currently projected telecommunications limit of 37 AU, 1 dB uncertainty represents more than 4 AU and almost 2 years of time. At this point, ±0.5-dB uncertainty in the performance values shown in Fig. 2 would probably be prudent.

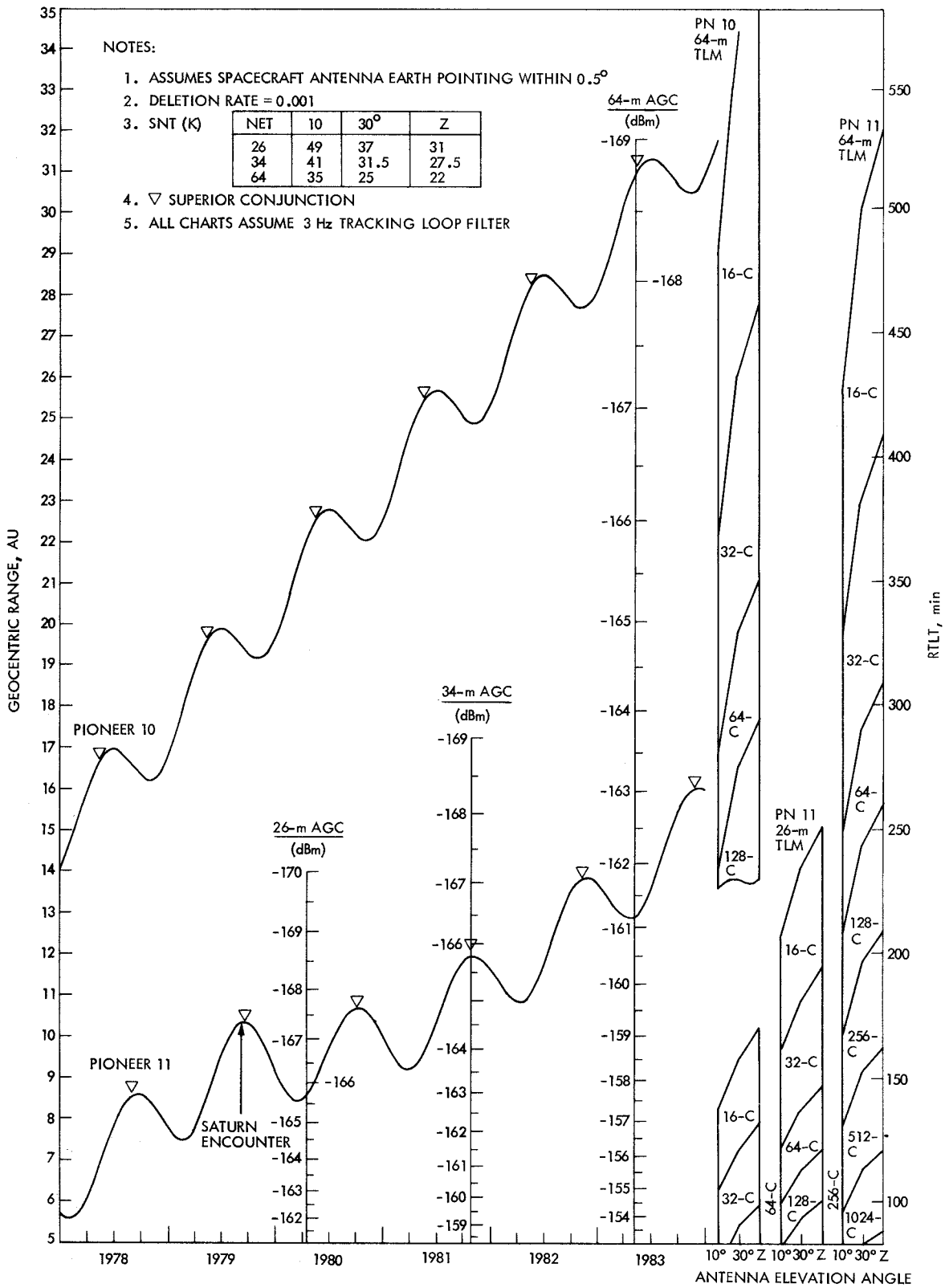
Acknowledgment

Figure 1 was provided by the Network Operations Telemetry Analysis Group.

References

1. Miller, R. B., "Pioneer 10 and 11 Mission Support," in *The Deep Space Network Progress Report 42-33,* pp. 21-25, Jet Propulsion Laboratory, Pasadena, Calif., March-April 1976.

2. Miller, R. B., "Pioneer 10 and 11 Mission Support," in *The Deep Space Network,* Technical Report 32-1526, Vol. XVI, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1973, pp. 15-21.



NET	10	30°	Z
26	49	37	31
34	41	31.5	27.5
64	35	25	22

Fig. 1. Downlink performance estimates for Pioneer 10 and 11

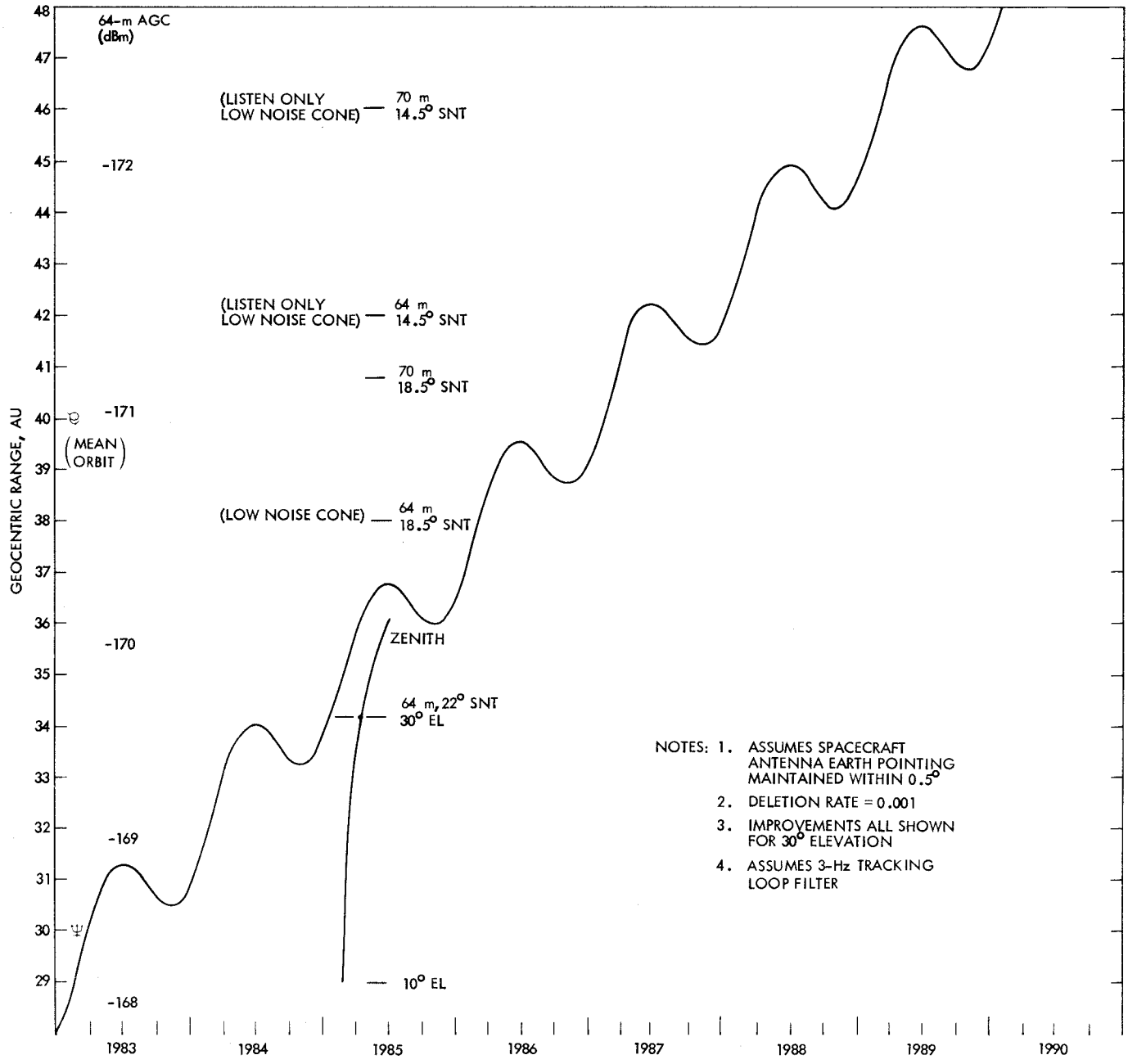


Fig. 2. Downlink performance estimate for Pioneer 10